Qualification of PV Materials

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Outline

- Material Considerations in Photovoltaic Modules
- Stresses in PV Module and Materials in the Service Environment
- Backsheet Failures in the Field Due to UV Damage
- Need for Additional UV Testing
- UV Test Protocols and Justification
- Conclusions

Material Combinations Create Unique Interactions

B

Module Encapsulant Resins

Elvax®

A

Front Sheet Materials

Teflon® films

B

Module Encapsulant Sheets

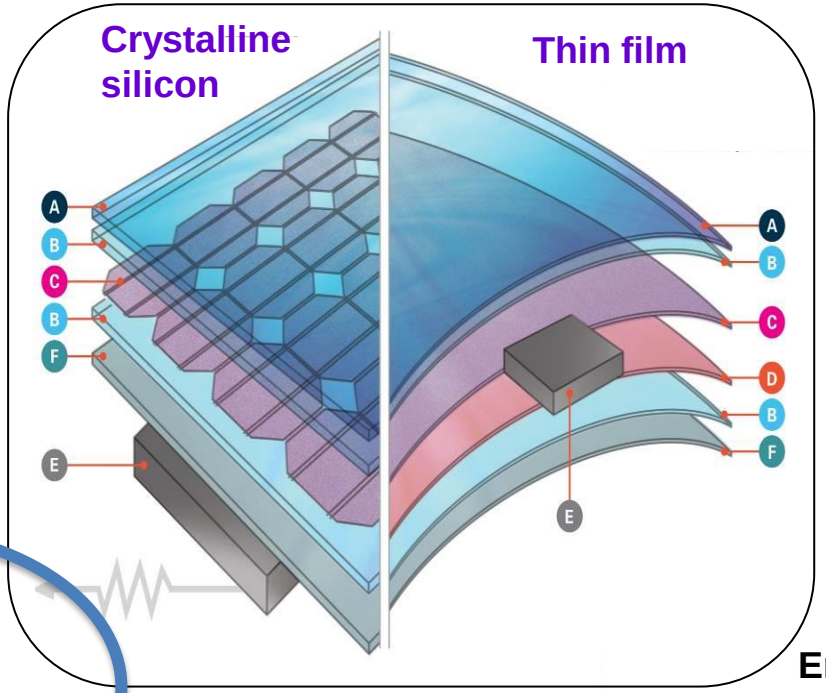
DuPont™ PV5200

DuPont™ PV5300

C

Cell metallization pastes

Solamet®



D

Thin Film Substrates

Kapton® polyimide films

F

Films for backsheets

Tedlar®

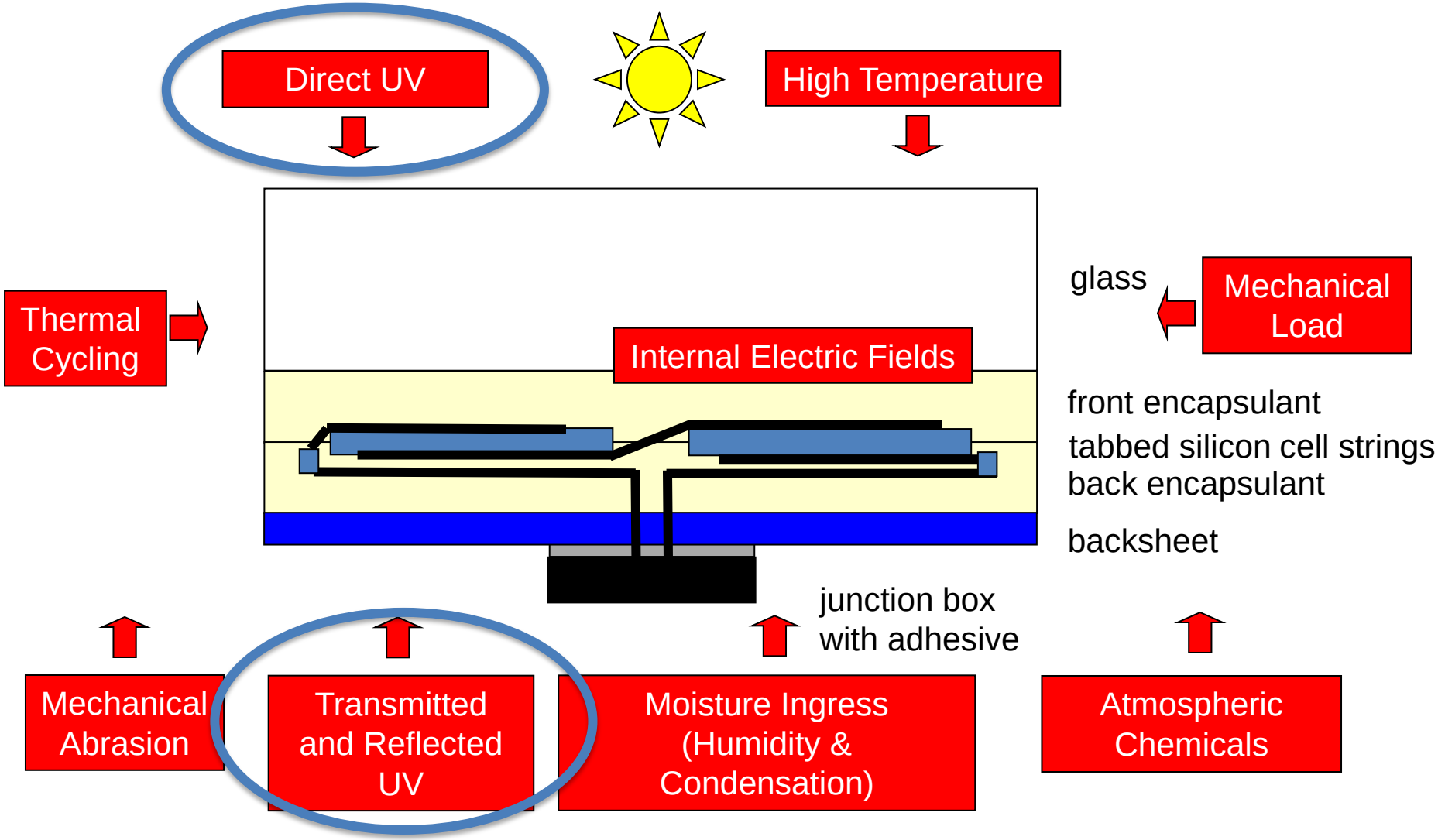
E

Engineering resins & components

Rynite®

Unique Opportunity for Deep Understanding of Performance

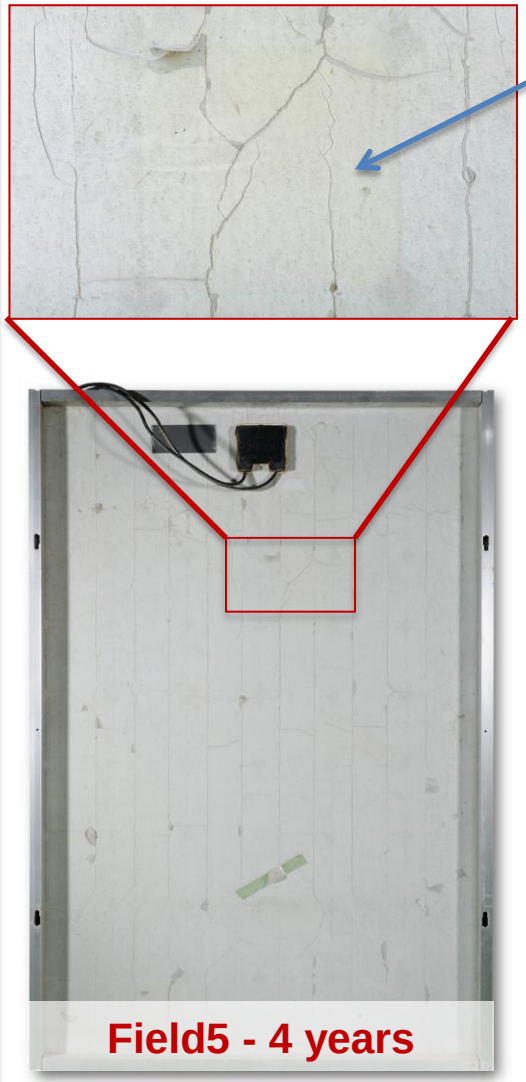
Stresses for PV Modules and Materials



- Combined stresses operate throughout greater than 25 year module lifetime
- Backsheet is the first line of defense in all geographic locations and installations
- **UV durability has been under-tested and its effects in the field under-estimated**

Module Failures due to UV Exposure: Polyester Yellowing and/or Cracking on Junction Box Side

Spain



Field5 - 4 years

Cracking & Yellowing

Yellowing

Arizona, USA

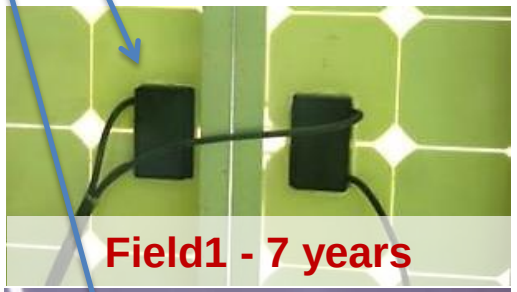
Field6 - 6 years

Failures from UV damage observed in the field early in expected module lifetime

Italy

Field2 - 9 years

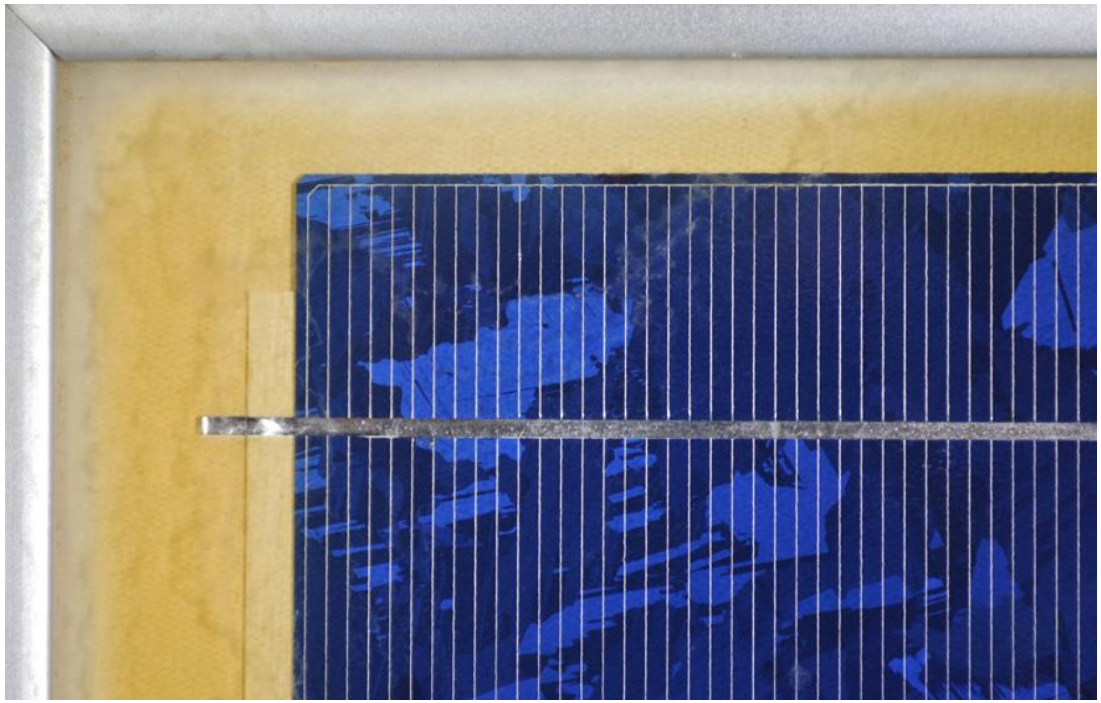
Field4 - 8 years



Field1 - 7 years

Field3 - 9 years

Module Failures due to UV Exposure: PVDF Front Side Yellowing



Front side yellowing observed in:

- 5 different countries (Belgium, Spain, USA, Israel and Germany)
- 5 different module manufacturers
- **Modules less than 5 years in the field**

Failures from UV damage observed in the field early in expected module lifetime

Need for Backsheet UV Testing

- Durability issues related to the backsheet are observed and documented in fielded modules (cracking, yellowing, delamination)
- We propose to add backsheet UV exposure to current industry standard (currently little or no UV exposure in qualification standards) consistent with the service environment
- Polymeric component testing of UV stability established in ASTM standards and used in other industries
  - Testing designed for easy adoption and implementation using existing equipment, methodology, and duration less than six months
  - Key properties and acceptance criteria consistent with industry protocols and field experience
  - Module testing limited by equipment, exposure time and established test methodology

DuPont Testing Protocols

Test	Exposure Condition	Evaluation	Technical Reason
Damp Heat	85°C, 85%RH	1000h	adequate for PET hydrolysis damage
		2000h	assess materials stability
		>3000h	test-to-failure
UV (Junction Box Side)	UV, 70°C BPT, 0.55 W/m²-nm at 340nm, ~60 W/m² (300-400nm)	275 kWh/m² (4230 h)	desert climate(25 year equivalent)
		235 kWh/m² (3630 h)	tropical climate (25 year equivalent)
		171 kWh/m² (2630 h)	temperate climate (25 year equivalent)
UV (Encapsulant Side)	UV, 70°C BPT, 1.1W/m²-nm at 340nm, ~120 W/m² (300-400nm), glass/EVA/EVA filter, std. EVA and UV transmissive EVA	550kWh/m² (4600 h)	desert condition (6 - 16 year equivalent)
		550 kWh/m² (4600 h)	tropical condition (7 - 19 year equivalent)
		550 kWh/m² (4600 h)	temperate condition (10 - 26 year equivalent)
Thermal Cycling	-40°C, 85°C, 200cyc	1x, 2x, 3x	assess durability
Thermal Cycling Humidity Freeze	-40°C, 85°C (50cyc); -40°C, 85°C 85%RH (10cyc)	1x, 2x, 3x	assess durability

* IEC 61215 UV pre-conditioning, 15 kWh/m² (280-385nm), **front exposure only, ~70 days outdoors**

- UV testing needs to be extended to adequately address backsheet performance in the outdoor environment
- Dosage for UV testing should match 25 year outdoor exposure to insure durability. Assumes a 12% albedo exposure on junction box side.
- Damp heat testing to 1000 hours is more than sufficient for PET hydrolysis damage of backsheets over 25 years of outdoor exposure

UV Durability Test Conditions for PV Backsheet

1. **UV Junction Box side exposure:** Xenon (daylight) or UVA fluorescent exposure, 70C BPT, 275 kWh/m2 TUV, ~25y desert exposure**)
    1. Test free-standing backsheet

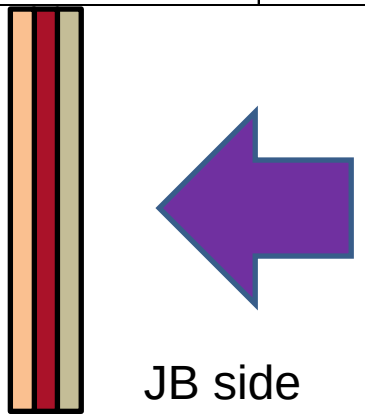
2. **UV Encapsulant side exposure:** Xenon (daylight) exposure, 70C BPT, 550 kWh/m2 TUV, ~6y desert exposure)
    1. Test laminate and free-standing backsheet
    2. UV exposure through glass/2EVA/FEP filter
    3. Test using standard and UV transmissive EVA

	Desert	Tropical	Temperate
Annual UV Exposure (kWh/m2)*	**92**	**79**	**57**
25 year UV Exposure (kWh/m2)	2300	1975	1425
25 year JB-side Exposure (kWh/m2)**	**276**	**237**	**171**
Equivalent JB-side exposure @275 kWh/m2 (years)	25	29	40
Equivalent E-side exposure @550 kWh/m2 (years)	6	7	10
Equivalent UVT E-side exposure @550 kWh/m2 (years)	16	19	26
* Total UV exposure (300-400 nm), reference: Atlas			
** Assumes 12% albedo			

*** Assumes UVT EVA transmits >320nm and std EVA transmits at >370nm

Criteria for Junction Box Side Exposure

	Impact on Power	*Impact on Safety*	*Acceptance Criteria*	*Justification*
Mechanical				
Visual Appearance	Indicates materials degradation and associated loss in key protective properties	Indicates materials degradation and associated loss in key properties	no cracking, flaking, bubbling or failure of adhesive bonds	consistent with IEC61215
Tensile Strength	brittleness/cracking of the backsheet leads to accelerated corrosion of the electrical contacts	lower force needed to cracking of the backsheet and compromises the electrical insulation	>70% retention	consistent with UL 746C criteria and referenced in UL1703
Elongation	brittleness/cracking of the backsheet leads to accelerated corrosion of the electrical contacts	lower elongation results in cracking of the backsheet and compromises the electrical insulation	>70% retention	consistent with UL 746C criteria and referenced in UL1703
Optical				
Color Change (b*)	Yellowing indicates materials changes that could translate to reduced physical properties tensile, elongation, adhesion/delamination)	Yellowing indicates materials changes that could translate to reduced physical properties tensile, elongation, adhesion)	change in b* < 2.0	consistent with comparison of accelerated test and outdoor performance



UVA or UVX (daylight),
65W/m2 UV, BPT 70C,
275 kWh/m2, 4200h

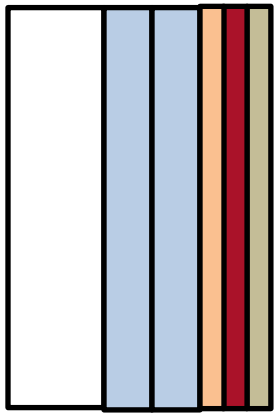
JB side

Criteria for Encapsulant Side Exposure

	Impact on Power	*Impact on Safety*	*Acceptance Criteria*	*Justification*
Mechanical				
Visual Appearance	Indicates materials degradation and associated loss in key protective properties	Indicates materials degradation and associated loss in key properties	no cracking, flaking, bubbling or failure of adhesive bonds	consistent with IEC 61215
Optical				
Reflectance	Lower reflectance reduces recaptured light from interstitial spaces at edge and between cells		change < 20% absolute	consistent with estimated 1% change in power
Color Change (b*)	Yellowing indicates materials changes that could translate to reduced physical properties tensile, elongation, adhesion/delamination)	Yellowing indicates materials changes that could translate to reduced physical properties tensile, elongation, adhesion)	change in b* < 2.0	consistent with comparison of accelerated testing and outdoor performance

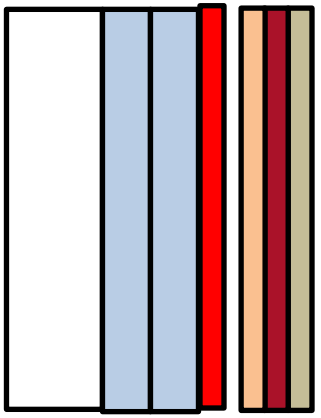
UVX (daylight), 120 W/m2, BPT 70° C, 550 kWh/m2, 4200h

UVT and std EVA



Laminate test

UVT and std EVA



Backsheet test

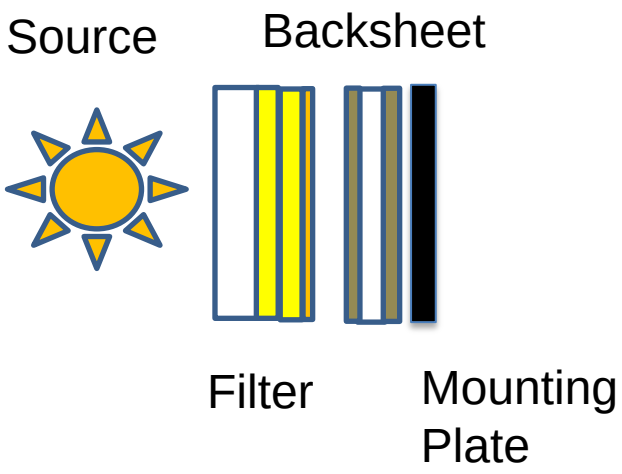
Using UV transmissive EVA to get higher acceleration, wavelength sensitivity and test range of commercial constructions. Mechanical retention criteria TBD.

Example: Test for encapsulant side backsheet stability

Simulates long term solar exposure from the glass side of a PV module with short wavelength (<360nm) light removed by glass/2xEVA filter.

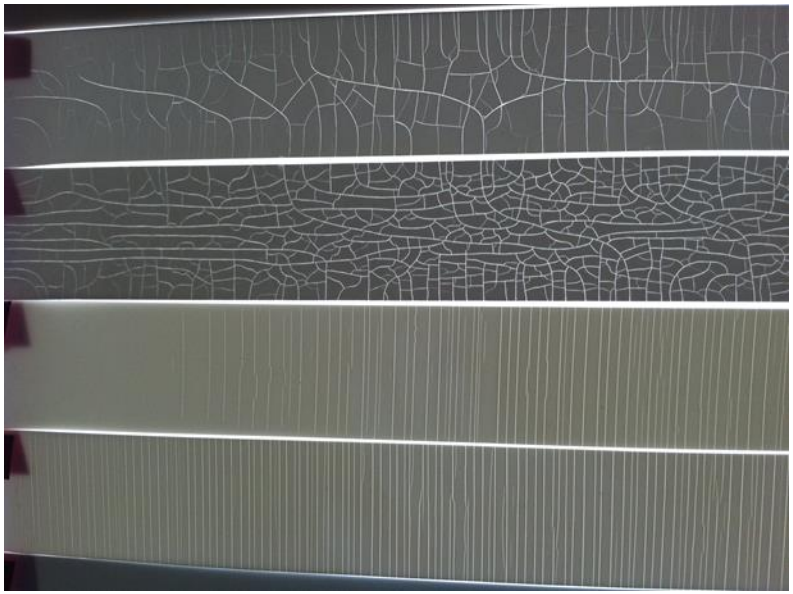
Source: 1500 W/m2 MH lamp
Filter: glass/EVA/EVA/FEP
Backsheets: various structures

Exposure Geometry



After 540kWh/m2 at 70C:
Some single sided backsheet showing instability of the inner layer

High intensity metal halide "filtered" exposures are showing changes to the inner layer of some backsheets



Conclusions

- Failures and degradation from UV damage observed in the service environment
- Current UV testing in qualification is not addressing UV stress in backsheets
- Improved UV testing is need to better predict durability of PV modules to stresses in the service environment
  - Reduces cost of long term testing
  - Provides insight into the material changes associated with property changes
- UV testing of components needed to predict their resistance to this stress in the outdoor environment
- UV test protocol developed to address encapsulant side and junction box side exposure based on outdoor environment